EXPERIMENTAL INVESTIGATION ON THERMAL BARRIER COATED PISTON HEAD (YSZ+Al_2O_3) BY USING COTTON SEED OIL AS A BIODIESEL.

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Abstract: ***Now a days research is going on to improve the engine performance. The object is to increase the engine efficiency by decreasing the in cylinder heat rejection. And improve the thermal fatigue protection of underlying metallic surfaces. For this Thermal barrier coatings are the useful once.***

In this project the piston head is coated with the yittria stabilised zirconium (YSZ) with aluminium oxide as a thermal barrier coating and NiCrAlY as a bond coat which helps to reduce the in cylinder heat rejection. Here YSZ is a low thermal conductivity material and Al_2O_3 is consider as an oxygen barrier structure and improves corrosive resistance. Thermal barrier coated with plasma spray method.

The performance of an internal combustion engines is affected when renewable biofuels are used instead of fossil fuels in a unmodified engine. By using Cotton seed oil with Al_2O_3 nanoparticles as a biodiesel. And investigate the HC, CO, CO_2, NO_x emissions.

I.Introduction:

Now a day there is a lot of automobiles are running on the roads which are used in transporting of passengers and goods from one place to another are working by using renewable resources like petroleum products. Some vehicles used petrol, and some other used diesel to run the vehicles and some vehicles run on the CNG (compressed natural gas). They are all non-renewable which take longer times to reproduce. If the resources are conserved then what are the immediate resources required to control the power surge, this is the main reason to go for the renewable resources and never to obtain situation of power surge among the world. Hence the new idea of renewable resources is evolved to replace the future but these are not in direct use there are certain procedures are needed to better use. What renewable resources are used to replace in petroleum products is the question raised and the results in invention of biofuels and biodiesels in order to support and replace of petroleum products. Biodiesels are fuels which are produced from plants and animals and bio wastes as well.

Here now days the better utilization of fuel is needed to loss minimum energy to the surroundings from combustion chamber of cylinder. Its means the improvement of thermal efficiency is the main factor to focus for designing of vehicles for this factor to be done we need additional support of materials to reduce the loss of temperature from cylinder to water jacket here are the some materials which have less thermal conductivity and less reactive metals are used for this purpose. The main aim of the materials using in the cylinders are to reduce the in cylinder heat rejection. We know the definition of Thermal efficiency that it's the ratio of heat utilized to the heat supplied by this heat rejection is decreased then the upper part of the division is increased and hence the thermal efficiency is improved. The using ceramic materials are called thermal barrier coatings. The different thermal barrier coating materials are zirconates, alumina, Mullite, Mgo, yittria stabilized zirconium etc.

The project main role is to improve the performance of engine. The performance parameters like thermal efficiency and the emission characteristics are analyzed by laying the thermal barrier coating on the piston head and along with the coating usage of biodiesel of cotton seed oil and conduct of experiment for performance parameters as well as emission characteristics are analyzed.

II.Literature review:-

Bulent Ozdalyan and Serkan Ozel are published a research paper on Experimental Investigation on Effect of the Zirconium + Magnesium Coating of the Piston and Valve of the Single-Cylinder Diesel Engine to the Engine Performance and Emission. In the published paper they are done research on thermal barrier coated materials using aluminum oxide, zirconium oxide and magnesium oxide in different percentages with 5 different (ZrO2 + MgO), (ZrO2 + MgO + 25% Al2O3), (ZrO2 + MgO + 50% Al2O3), (ZrO2 + MgO + 75% Al2O3), (Al2O3) sample. Are used the coatings on piston are done by using the plasma spray technique and he concludes that At the end of material analysis, the best result in the ZrO2+MgO added Al2O3 coating appears in the sample no A3 with addition of the 50% Al2O3. The reason of this can be explained that expansion coefficient of the ZrO2+MgO is less than the expansion coefficient of the Al2O3. This difference affects the pore amount of the material, and it provides material more stable. In this analysis he conclusion is that improve the aluminum oxide layer thick ness along with other layers gives us a best results of material stability.

Mohsen saremi and Akira kobayashi are done research on "Microstructure analysis of YSZ AND YSZ/Al_2O_3 Plasma sprayed thermal barrier coatings after high temperature oxidation ". In this research paper he conduct a research on by varying thermal barrier coated materials like YSZ on NiCrAlY bond coat and Al_2O_3 with bond coat separately and tested and concludes that Aluminum oxide has good stability and helps to reduce the oxygen passes through the coat. By combining of aluminum oxide and yittria stabilized zirconium as a layer on top and middle respectful to improve the properties of layer like stability and durability he concludes in his experiment.

Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method paper published by S.Srikanth Reddy, Dr. B. Sudheer Prem Kumar in this paper thermal barrier coated aluminium alloy piston by zirconium material to analysis the stress distribution around the piston by using design and analysis software. Here the piston is designed using software of computer aided design of NX Catia here the piston dimensions are calculated according to the requirements. And the material properties of aluminum oxide and zirconium are calculated and laid a layer of thickness and applied different loads and temperatures to find the stresses and thermal stress and find out how the stress distribution may vary along with the different temperature ranges. The finite element stress analysis is done by using computer aided simulation software ANSYS.

Nano particle as a additive in biodiesel on working characteristics of DI diesel Engine the research paper was published by A.Prabu from NIT tiruchi in this project the biodiesel used is Jatropha biodiesel and along with the nanoparticles of cerium oxide and Aluminum oxide B20A30C30 is significantly improved by comparing to B100. Here we can understand that by using nanoparticles we can reduce or control the emissions along with the biodiesel. By using of nanoparticles the brake thermal efficiency is also can be improved.

Cotton Seed Biodiesel as Alternative Fuel: Production and its Characterization Analysis using Spectroscopic Studies research paper published by Hariram Venkatesan , Godwin John and Seralathan Sivamani. In this research the main aim is to conversion of raw cotton seed oil into alternative fuel by using trans esterification process. Here they use single stage trans esterification technique is adopted. Methanol, KOH and raw cotton seed oil is used in the base catalyzed trans esterification. To maximize the biodiesel production is noticed by optimizing the methanol oil molar ratio and catalyst concentration.

III.Thermal barrier coatings:-

Thermal barrier coating materials are the materials which should have the properties like material should have higher melting point and no phase transformation between room temperature and operational temperature. The material should have low thermal conductivity and chemical inertness. Coefficient of thermal expansion should match with the metallic substrate. It should have good adherence properties and low sintering rate of porous micro structure. The materials are uses as a thermal barrier coating.

The process laying ceramic coating material on the substrate is follows a process first the bond coat is laid to support the coating on the substrate. Second layer is the yittria stabilized zirconia of 200microns helps to prevent the transfer of heat to the piston. And the upper layer is laid with the coating alumina oxide which gives the coating stability and prevents the oxygen to go further to form a thermally grown oxide layer in the coating which causes coating to decrease in strength.

The coating is layered by using plasma spray technique in which high temperature plasma spray with high velocity of plasma gas either of hydrogen, nitrogen, argon, helium is used to deposit the ceramic layer coating on the piston, The heated and accelerated particles are impacts the material by sudden cooling of the coating this process is called cold process

Specifications of thermal barrier coating:-

Total thickness of ceramic coating: 550 microns

Bond coat: NiCoCrAlY-alloy -150 microns

YSZ (yittria stabilized zirconium) – 200 microns

Aluminum oxide – 200 microns

Coating method – plasma spray technique

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Figure: thermal barrier coated piston

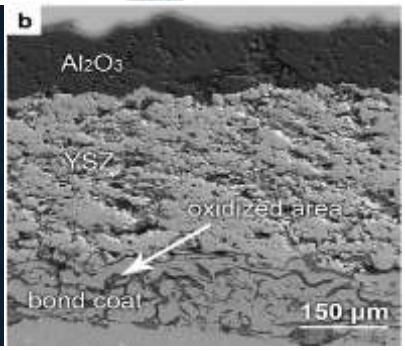


Figure: microscopic view of coating

IV.Biodiesel and additives:

Cotton seed oil used as an alternative fuel in this experiment which is extracted from cotton seeds. Cotton seed oil which is obtained is through extraction process is not directly used as alternative fuel. The Trans esterification process is done to where the tri glyceride oils are reacted with methanol in presence of catalyst like KOH or NaOH and separates the mixture of fatty esters and glycerin, the fatty esters are used as an alternative fuels.

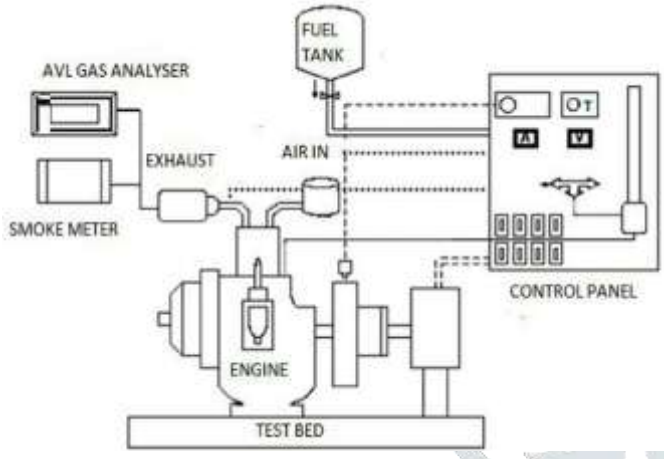
Aluminum oxide additive: aluminum oxide nanoparticles are improves the consumption of oxygen and help to improve the performance as well as used to show good results in emission characteristics.

Figure: cotton seed biodiesel

figure: aluminum oxide additive

Properties	Diesel	B-10	B-20	B-20+ 100ppm Al_2O_3	B-25	B-100
Density(Kg/m^3)	830	834	840	848	846	864
Calorific value (KJ/Kg)	45,020	44,120	43,380	43,620	42,960	40,800
Viscosity at 40℃ (Cst)	3.8	4.03	4.12	4.20	4.24	4.9
Flash point (℃)	52	56	61	62	65	140
Fire point (℃)	58	60	64	65	69	168

ENGINE SPECIFICATIONS:



Engine	KIRLOSKAR 4 stroke-stationary.
Type	water-cooled
Injection	direct injection (DI)
Maximum speed	1500 RPM
Number of Cylinders	one
Bore & Stroke	80 mm & 110 mm
Compression Ratio	16.5:1
Maximum HP	5 HP

V.Experimental procedure:

The experiment is done to find the performance and emission characteristics of an engine. Here step by step procedure is followed to do calculations. At first the uncoated piston is fitted in the diesel engine cylinder arrangement. And the procedure to run the engine by giving the power manually by rotating the Fly wheel and allow the charge into the cylinder. After running with the diesel fuel we have an arrangement in experimental setup that the fuel burette of 50 cc measurements is arranged in the way that even if we switch of the flow from tank it has the fuel quantity of 50 CC.

Make the run of engine for 15 minutes before taking the reading. By cutoff the fuel flow from fuel tank then we have to take the time taken to measure the consumption of 10 CC of fuel and make it note at take the temperature readings of inlet air and water temperature and exhaust gases outlet and water outlet temperatures are recorded by taking the values by digital arrangements which are run by thermocouples as a source to read temperatures by sensors.

The speed of Engine is kept constant at 1500 RPM by adjusting the governor arrangement through screw adjuster. For varying the load we have to put the loads around drum like arrangement and the water is continuously supplied throughout the engine and drum with the help of motor to maintain cooling effect around the setup. The time taken for collecting 10 CC of fuel is taken by varying the different loads, after varying each load the waiting time to take the reading is around 15- 20 minutes. In the experiment the taken loads are no load (zero load), 3Kg , 6kg, 9kg, 12 kg. at each load different brake power is produced. By calculations brake thermal efficiency and specific fuel consumption of particular fuel is measured at different loads. The procedure is repeated by installing the thermal barrier coated piston in the place of uncoated piston by removing the uncoated piston by disassembling the cylinder head arrangement. By proper arrangement of piston then repeat the procedure to run the engine with diesel fuel and different blends of cotton seed methyl esters with diesel in the proportions of B-10, B-20, B25, B-20 + 100PPM of aluminum oxide.

After calculating every value of performance parameters they are to be compared by plotting the graphs between brake power and brake thermal efficiency, brake power and specific fuel consumption, brake power and other performance parameters like indicated thermal efficiency, mechanical efficiency etc**.**

VI.Results and discussions:-

Brake thermal efficiency:-

Brake thermal efficiency is the ratio of brake power to the heat input which is the product of total fuel consumption and calorific value. Here the blends using are uncoated diesel, coated piston with D-100, B-10, B-20, B-20 along with the 100ppm of Aluminum oxide, B-25. By through observation of graph we can conclude that the brake thermal efficiency is increases with the brake power and the improvement growth is decreasing while reaching to the maximum load condition. The uncoated diesel engine has less thermal efficiency while compare to the coated piston thermal efficiency due to reduction of less heat loss.

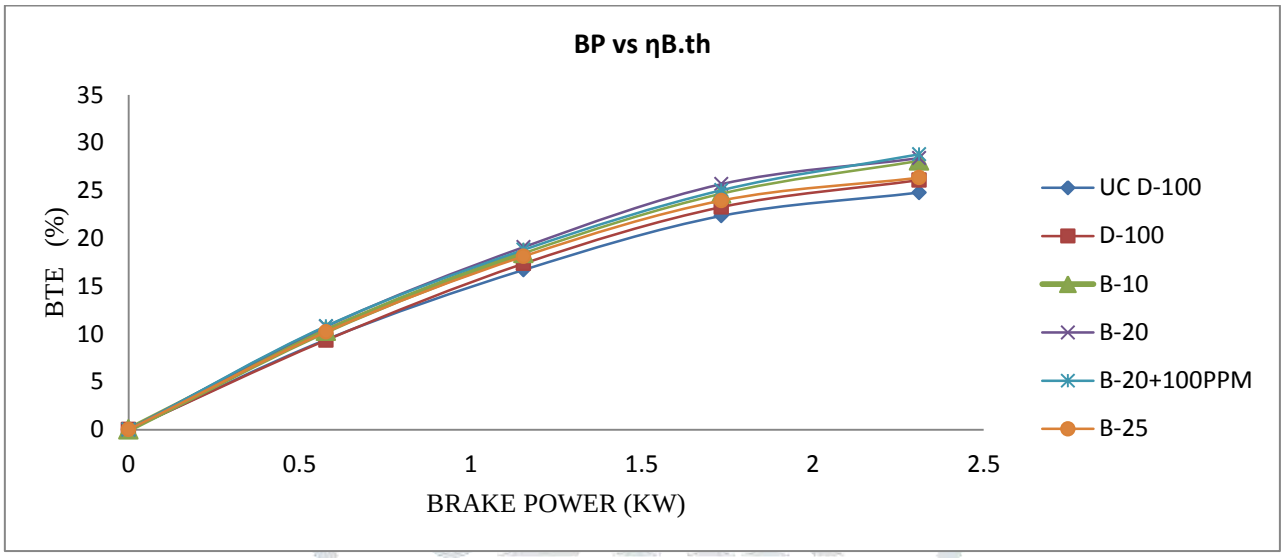


Figure: Brake thermal rate variation

By using of cotton seed oil along with the thermal barrier coating the thermal efficiency is increases in the way of B-10 to B-20 and B-20 along with the nanoparticles but it decreases to the B-25 blend it attains the maximum at the blend of B-20 with the coated piston. The thermal efficiency is improved by 3% when compared to the uncoated to the coated with B-20 blend

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Brake specific fuel consumption:

The brake specific fuel consumption is the rate of amount of fuel is consumed by an engine for producing the unit power output. The variation in specific fuel consumption with brake power for normal piston and the coated piston along with the different blends (UC D-100, D-100, B-10, B-20, B-20 + 100 ppm of aluminum oxide and B-25). Specific fuel consumption is not only depends on input power but it depends on many factors. Here in the graph observations the specific fuel consumption is the uncoated piton with diesel has high SFC at low loads when compared to coated piston and increases in brake power the situation is vice versa. Blend with B-20 + 100 PPM has lesser BSFC consumption and it shows good results the lesser the SFC the better the fuel shows its response. The variation in fuel consumption to produce unit power varies around 0.1 units of SFC.

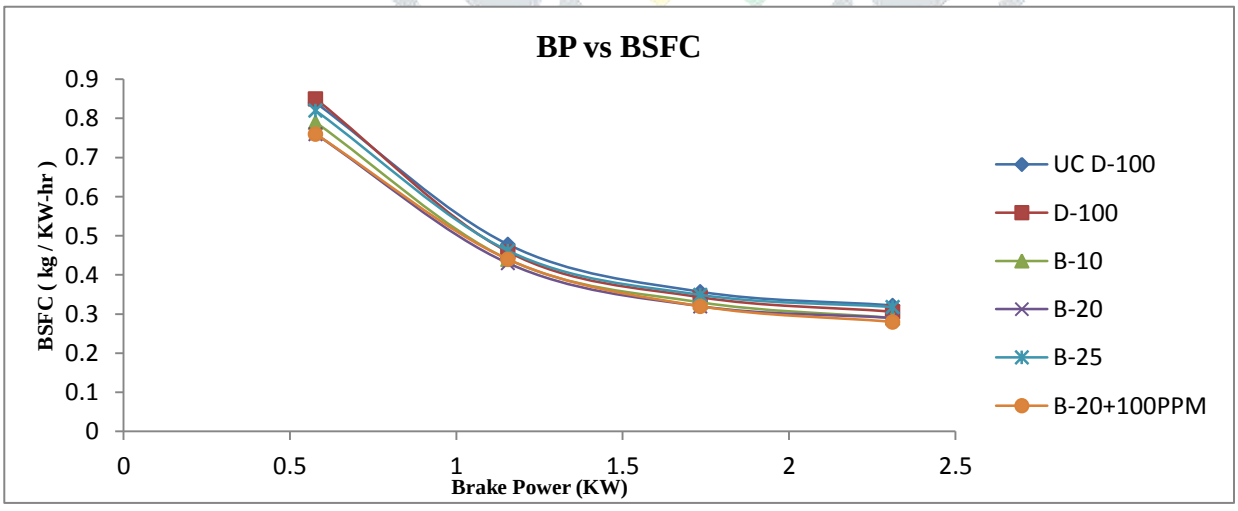

Figure: Rate of variation in Brake specific fuel consumption

VII.Emission measurement:

Unburnt Hydro carbons:-

The fuel is nothing but the combination of different physical arrangement of hydro carbon chains in combustion some of hydro carbons that are present in the fuel are not get burnt such type of hydrocarbons are ejected as emissions, they are called as un burnt hydro carbons. Here by conducting emission test with EGR (Exhaust Gas Analyzer). In this graph we can observe that the hydro carbon emissions are going to reduce by using the thermal barrier coating, and further introduction in blends the hydro carbon emissions are reduced and at B-20 + 100 PPM aluminum oxide has released less amount of hydro carbons are released when compare to other blends, by increasing in blend ratio the un burnt hydrocarbon quantities are reduced up to B-20 and after that the quantity goes rises up. It's better to use up to B-20 to better operating functions of hydro carbon emissions.

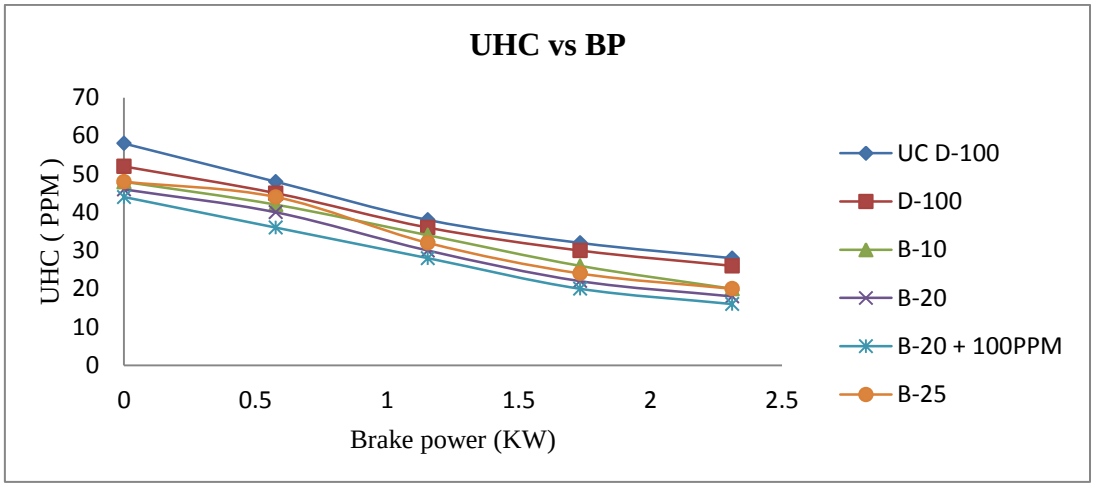

Figure: Variation of Unburnt hydrocarbons

Carbon monoxide emissions:-

Here the carbon monoxide emissions are measured in percentage of volume, and the emissions are produced due to presence of lack of oxygen in the combustion chamber while burning the mixture. The carbon monoxide is high for uncoated piston with diesel as fuel. By coating the piston the emissions of CO are reduced and further blending the diesel fuel with the co emissions are decreasing in accordance. By blending with the cotton seed oil the co emissions are decreased in the order from B-10 to B-20 and further increase in blending improves the carbon monoxide emissions. And the emissions are less for B-20 with using of 100ppm of Aluminum oxide. The variation is around 0.1 % in comparing. As a brake power increases the co emissions are increased in accordingly due to the increase in fuel quantity in the fuel air ratio.

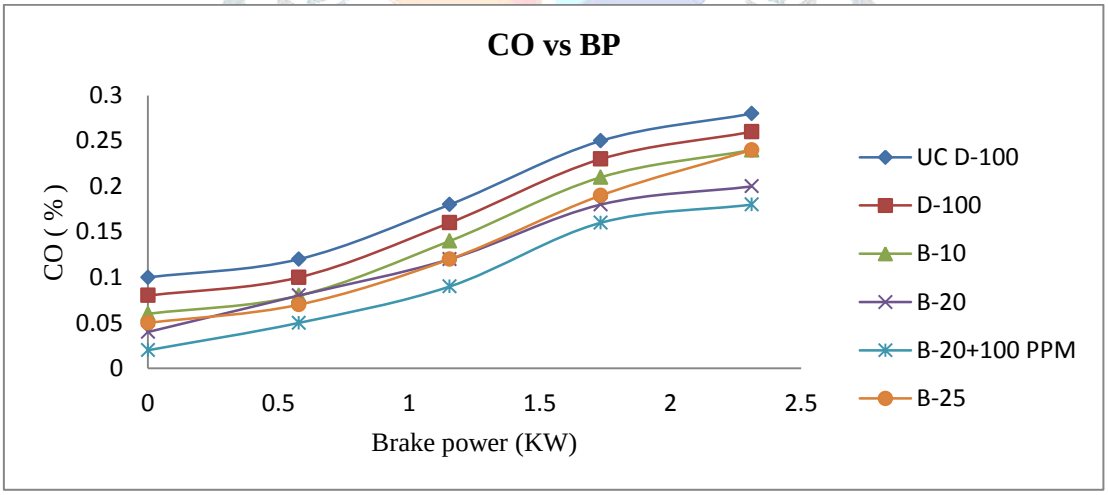

Figure: Carbon monoxide vs. brake power

Nitrogen oxide emissions:-

Nitrogen oxide emissions are formed due at high temperature nitrogen which is present in atmospheric air is reacted with oxygen and formed oxides of nitrogen. The graph is drawn between brake power to the nitrogen oxides and by increasing the brake power the nitrogen oxides are improved. By using thermal barrier coatings the in cylinder temperature increases then the increase in NO_x emissions too. By using the cotton seed oil as alternative fuel blends the NOx emissions are further improved from B-0 to B- 20 and further improvement in blending causes decreases in emissions due to decrease in in cylinder temperature. The NO_x emissions are high at a blend of B-20 with 100 ppm of Aluminum oxide. The maximum NO_x emissions that are exhausted are 840 PPM at 12kg of load and the emissions are less at lesser loads and high at higher loads by this increase in NO_x emissions are due to increase in loads, by increase in loads the in cylinder temperatures are increases. The NO_x maximum varies around 200 ppm by using blends. By using cotton seed oil as a blend then the NO_x emissions are increasing rapidly.

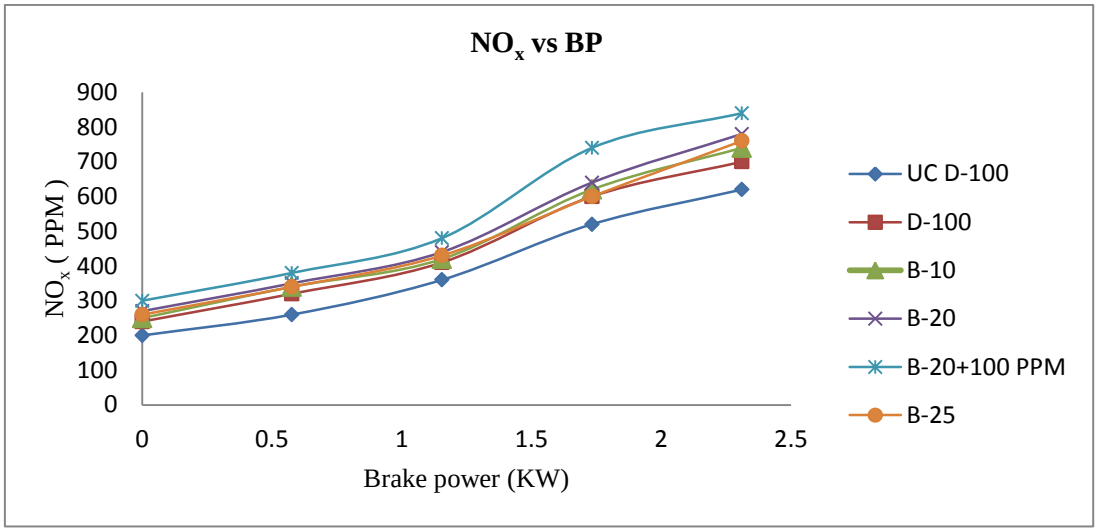

Figure: NO_x vs. Brake power graph

VIII.Conclusions:

In this experiment the performance and emission characteristics are analyzed by coating the piston head with thermal barrier coating. Here the cotton seed methyl ester is used as alternative fuel in different blends D-100, B-10, B-20, B-20 + 100 PPM of Aluminum oxide, B-25. By keeping the speed of flywheel constant by varying the loads.

By observations the brake thermal efficiency is improved to 1.3% for coated piston while compare with uncoated piston. And thermal efficiency is 2.5% higher at B-20 + 100 ppm of aluminum oxide while compared to coated piston using diesel fuel.. And specific fuel consumption is also low at B-20 with aluminum oxide additive which shows good results, at higher loads thermal efficiency is good by using cotton seed biodiesel blends. Thermal efficiencies are improved by increasing the blending up to B-20 and then they fall down it shows that optimum results are obtained at 20% of cotton seed biodiesel. Coated piston with biodiesel shows good results while compare to the uncoated ones it shows that by thermal barrier coatings the thermal efficiencies are improved.

By observation of emission graphs we conclude that the uncoated piston have less NO_x emissions while compare to coated ones. By ceramic coatings the in cylinder temperatures are raises which results in improvements in emission of NO_x. The CO, HC emissions are decreased by using the cotton seed oil and they are low at B-20 + 100 ppm of aluminum oxide. By adding the additive the CO and HC emissions are reduced.

Ceramic coatings are not as stable they are degraded after continuous run for several hours it needs to be more stable. And by this study we can conclude that using of blends with ceramic coatings improve the performance of engine and less CO,HC emissions are produced apart from the NO_x emissions.

References:

[1] Cotton Seed Biodiesel as Alternative Fuel: Production and its Characterization Analysis using Spectroscopic Studies Hariram Venkatesan , Godwin John, Seralathan Sivamani Department of Mechanical Engineering, Hindustan Institute of Technology & Science, Hindustan University, Chennai.

[2] New Bond Coat Materials for Thermal Barrier Coating Systems Processed Via Different Routes A Soare, I Csaki, M Sohaciu, University Politehnica Bucharest, Romania.

[3] Thermal diffusivity characterization of bond-coat materials used for thermal barrier coatings by Grzegorz Moskal, Anna Jasik.

[4] Experimental Investigation on Effect of the Zirconium + Magnesium Coating of the Piston and Valve of the Single-Cylinder Diesel Engine to the Engine Performance and Emission Erdinç Vural, Bülent Özdalyan, Serkan Özel.

[5] Thermo Mechanical Analysis of a Piston with Different Thermal Barrier Coating Configuration by Dipayan Sinha, Susenjit Sarkar and Samar Chandra Mandal Jadavpur University, Kolkata.

[6] Thermal barrier coating on IC Engine Piston to enhance better utilization of heat produced inside the combustion chamber ultimately improving engine's efficiency by Mohsin Attar, Ajay Bhongade, Bharti Vidyapeeth College of Engineering, Kharghar.

[7] THERMAL BARRIER COATINGS IN INTERNAL COMBUSTION ENGINE by K. Thiruselvam Department of Mechanical Engineering, Panimalar Engineering College, Chennai.

[8] Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method by S. Srikanth Reddy and B. Sudheer Prem Kumar, JNTU College of Engineering Hyderabad.

[9] Thermal Analysis Of Ic Engine Piston Using Finite Element Method by Shirisha, G.S.Dk.Sravani, PG Scholar, Pydah College of Engineering, Kakinada.

[10] Thermal barrier coating on IC Engine Piston to improve Engine efficiency Balbheem Kamanna, Prof. Bibin Jose, Department of Mechanical Engineering, MGM College of Engineering, Navi Mumbai.

[11] Performance and emission analysis of cotton seed oil methyl ester in a diesel engine by husein aydin, hasan bayindir dicle university, turkey.

[12] Evolution of biodiesel obtained from cotton seed oil by Umer Rashid, Forooq Anwar, Gerhard knothe.biochemical university of agriculture, Faisalabad.

[13] A comparative study on hot corrosion resistance of three types of thermal barrier coatings YSZ, YSZ+Al_2O_3 Abbas afrasaibi, Mohsen saremi, Akira kobayakshi, university of Tehran, Iran.

[14] Nanoparticles as a additive in biodiesel on the working characteristics of a DI diesel engines by A.Prabu Natinol institute of Technology, Tiruchunapalli.